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Using Technology to Engage Students in the STEM Field

By:

April Elizabeth Steen

A thesis submitted to the faculty of the University of Mississippi in partial fulfillment of the requirements of the Sally McDonnell Barksdale Honors College

Oxford

May 2015

Approved by:

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ABSTRACT

APRIL ELIZABETH STEEN: Using Technology to Engage Students in the STEM Field

(Under direction of Dr. Nathan Hammer)

The United States is currently facing a shortage of qualified STEM professionals in the workforce and in research fields. Part of this lack of professionals can be traced back to lack of interest and lack of proficiency in mathematics and science at the secondary level of education as well as STEM major attrition at the college level. In an effort to increase student interest in STEM fields and increase retention of STEM majors, technology was employed to engage student interest. At the high school level, a physical chemistry demonstration on the spectroscopy of light was created. The demonstration was presented at a high school. In order to further engage student interest and encourage hands-on learning, the class was allowed to participate in the gathering of spectra. By analyzing students' answers to pre-demonstration and post-demonstration assessments in addition to a demonstration feedback form, the effectiveness of the demonstration in teaching the intended concepts was analyzed. At the college level, a website was created for the Ole Miss Physical Chemistry Summer Research Program and the Research Experience Undergraduate program. The old Ole Miss PChem Summer Research Program website was updated in order to increase visual appeal, ease of navigation, and amount of information disseminated. A new REU program website was created to integrate into the PChem website and provide information specifically about the REU program. These websites were created in the hope of increasing student interest and involvement in the programs as well as retaining students in programs that lead to STEM majors.

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1 Introduction

1.1 Need to Engage Students in STEM Fields

The United States is currently experiencing a STEM crisis. It is expected that by 2018, there will be a shortage of three million high-skilled workers in the STEM field.¹ In 2008, 59% of all jobs required post-secondary education and training; by 2018, this number is expected to increase to 63%. Also by 2018, it is expected that 92% of STEM jobs will require post-secondary education and training. There is a dire need for more qualified STEM workers in the United States work force. Another problem facing the U.S. STEM job market is the underrepresentation of certain groups. Although women make up almost half of the workforce, only 23% of STEM workers are women. In addition, although non-Hispanic black and Hispanic individuals make up 25% of the workforce, only 12% of the STEM workforce is represented by these racial groups. Steps must be taken to increase these minority groups' involvement in the STEM fields. In addition to a shortage of qualified professionals in the STEM workforce, there is a shortage of STEM researchers. In 1981, 40% of all publications in major STEM research journals were by U.S. scientists; by 2009 this number had fallen to 29%. Also by 2009, over half of the awarded U.S. patents were given to foreign companies due to shortcomings in the STEM fields.² The STEM crisis has roots in issues at both the secondary and post-secondary levels of education.

When looking at STEM readiness statistics for high school students, a discouraging pattern emerges. As of 2013, only 44% of high school graduates are prepared for college-level math courses while only 36% are prepared for college-level science courses. In 2009, only 21% of graduating high school seniors scored at least proficient on standardized science tests.² According to ACT test data from 2008, only 17.3% of all high school seniors both showed proficiency in mathematics and expressed an interest in pursuing a STEM degree. Another 25.4% expressed an interest in a STEM degree but did not show proficiency in mathematics.³ Part of the issue driving the lack of proficiency in math and science is a lack of highly qualified STEM teachers. As of 2007, 33% of middle school science teachers and 36% of middle school mathematics teachers at public institutions either did not major in their subject area or were not certified to teach it.² These discouraging statistics have caused the White House to implement measures, such as the \$40 million STEM Teacher Pathways program, to retain over 100,000 highly qualified STEM teachers at the secondary education level.⁴ The STEM crisis cannot be averted, however, by just focusing on STEM education at the secondary school level; efforts must be made to retain STEM college undergraduates.

As of 2009, STEM majors accounted for 28% of all bachelor's degrees and 20% of all associate's degrees; however, over 48% of the bachelor's degree students and 69% of the associate's degree students exited the field either by switching to a non-STEM major or by dropping out of college. Of those leaving the STEM fields, women, underrepresented minorities, low-income students, students with weaker academic backgrounds, and first-generation students showed higher rates of exit than their counterparts. To help reduce this attrition and increase the number of STEM graduates, a

number of measures have been taken. Some schools implement bridge and cohort programs to foster increase students' sense of connection both to their programs and to their peers. Other schools implement programs such as summer research experience for undergraduate programs to foster relationships between faculty and students, to foster relationships between students and their peers, and to increase students' interest in their chosen field.⁵ By focusing on fostering interest in STEM fields and increasing students' proficiency in mathematics and science at both the secondary and post-secondary levels of education, it is hoped that the United States will be able to meet the demand for STEM majors and reverse the current STEM crisis.

1.2 Using Technology to Engage Students in STEM Fields

1.2.1 Using Websites to Disseminate Scientific Information

In the 2013 census, 74.4% of all United States households reported internet use.⁶ As of 2014, 42.3% of the world's population had access to the internet.⁷ Internet usage has made communication and dissemination of information much easier in today's society than at any prior time in history. Whereas it might have taken weeks or months for discoveries to be reported to the scientific community or the general public in the past, with today's technology information can be shared almost instantaneously. The increase in the use of technology and the internet in research has also lead to an increase in collaboration between researchers in different groups. Today, more than 35% of all scientific research papers show international collaboration between peers.⁸ Many research groups, such as the Hammer lab at the University of Mississippi, have their own

websites to display information about their group's projects, publications, and members. These websites serve to inform other researchers, the general public, and potential future group members about the group's undertakings.⁹ Many students at universities will view group websites in an effort to locate a research group with projects that spark their interest. Using websites, it is possible to disseminate scientific information and inspire student interest in scientific research.

1.2.2 Using Hands-On Demonstrations to Encourage Interest in STEM

Studies have proven that hands-on learning helps inspire students' interest in learning, imparts content knowledge more effectively, and promotes longer retention time of knowledge. Hands-on activities offer a variety of benefits, including developing critical thinking skills, encouraging communication between peers, building language skills, helping disadvantaged students learn more, teaching teamwork, and increasing interest by making learning fun. Many teachers have found that incorporating hands-on learning in their classrooms also helps reduce distractions and increase student focus. In a 2011 survey of Resource Area for Teaching (RAFT) members, 99% of teachers that implemented hands-on learning reported their students retained information longer and were more engaged during the learning process.¹⁰ In the classroom, technology can be implemented in the hands-on learning process. Technology allows students to take an active role in the learning process. Students must actively make choices about the best ways to obtain, analyze, and present information. Technology also allows more students to actively participate in this process. Using technology in the classroom provides a

variety of benefits, including increasing motivation and self-esteem, increasing the level of technical skills, allowing more peer to peer collaboration, increasing use of outside resources, and allowing for the accomplishment of more complex tasks.¹¹ The use of hands-on learning and technology can be greatly beneficial when teaching STEM fields. Whereas students might otherwise passively learn about a scientific process and not go into much further detail during traditional lectures, hands-on experiments allow them to act as scientists and process information in ways that may make more sense to the individual student. Implementing hands-on experiments and technology when teaching STEM content knowledge could help increase students' interest in the information and help the student's retain the information more efficiently and for a longer period of time.

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2 Encouraging Interest in STEM Fields in Pre-College Students

2.1 Creation of a Hands-On Demonstration to Inspire Students' Interest in STEM

2.1.1 Introduction

Light is a unique type of energy that can exist in both wave and particle form. This property of light is known as its wave-particle duality. The wave form exists as electromagnetic radiation, which is composed of oscillating electric and magnetic fields situated perpendicular to one another. The particle form of light exists as discrete packets known as photons. Light carries energy. The energy of light has an inverse relationship to its wavelength and a direct relationship with its frequency. Light of longer wavelength and lower frequency has lower energy and light of shorter wavelength and higher frequency has greater energy. The energy of light is very important. High energy gamma rays can cause damage to biological molecules, such as DNA, and lead to a variety of illnesses. X-rays are capable of penetrating soft tissues and can be used to image bones underneath. Ultraviolet radiation can cause painful burns to the skin if exposure is too great. Visible light allows humans to visualize their world. Infrared radiation generates heat. Microwave radiation can be used to heat food or operate radar. Radio waves can be used to transmit information, such as music stations and cellular signal, wirelessly.¹ Using the Planck equation, it is possible to interconvert between the wavelength and energy of light or the frequency and energy of light. Equation 2.1 shows the form of the Planck equation when solving for energy using wavelength. In the

equation, E is the energy in Joules, h is Planck's constant ($6.626 \times 10^{-34} \text{ J}\cdot\text{s}$), c is the speed of light ($3.0 \times 10^8 \text{ m/s}$), and λ is the wavelength of light in meters.²

$$E = \frac{hc}{\lambda} \quad (2.1)$$

The electromagnetic spectrum is the broad range of all wavelengths and energies of light. It ranges from low energy radio waves, which can have wavelengths longer than 10^2 m , to high energy radio waves, which can have wavelengths shorter than 10^{-12} m . A diagram of the electromagnetic spectrum arranged in order of decreasing wavelength can be seen in Figure 2.1. As seen in Figure 2.1, the portion of the electromagnetic spectrum that is visible to the human eye is very small, only incorporating wavelengths between about 700nm and 400nm. The colors of the visible portion of the electromagnetic spectrum range from red at 700nm to violet at 400nm.^{1,2}

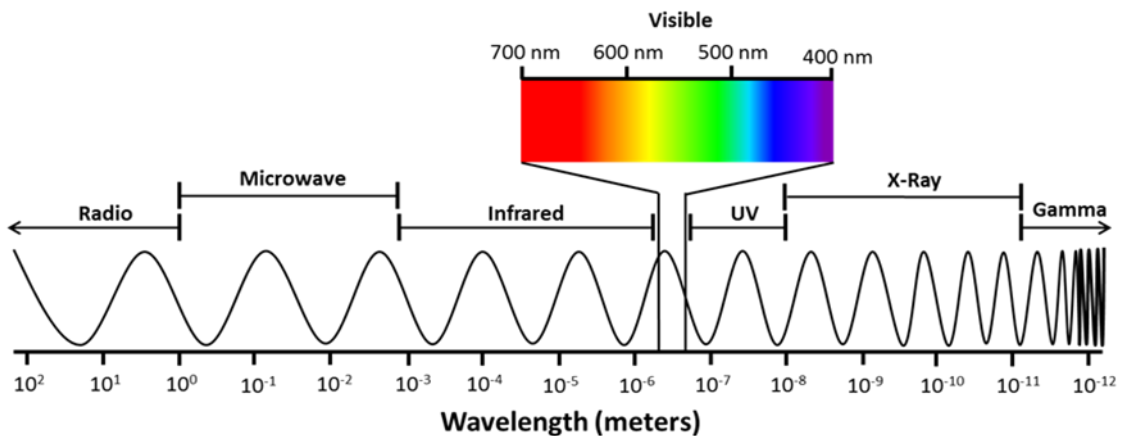


Figure 2.1 *The electromagnetic spectrum*

Light can be used in a variety of applications, including in spectroscopy. Spectroscopy is the study of light-matter interactions. When light is shone incident upon an atom or molecule, absorption can occur if the energy of the photon matches the energy

gap between a ground state in the atom or molecule and an excited state. To relax back down to the ground state, the atom or molecule can give off a photon during emission.² These processes of absorption and emission can be seen in Figure 2.2.

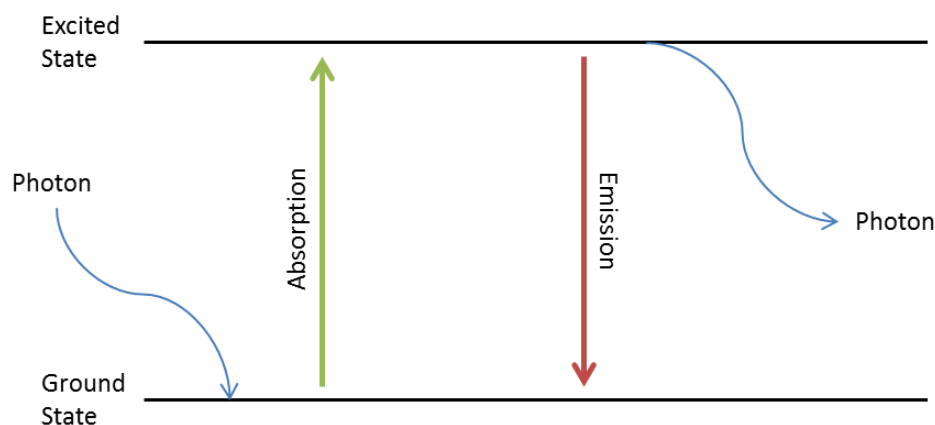


Figure 2.2 *Processes of absorption and emission*

When performing spectroscopic studies, you can choose to do either absorption spectroscopy or emission spectroscopy. Each atom or molecule exhibits specific patterns of absorption or emission of particular wavelengths of light. These patterns are known as spectra. Spectra are unique to the atoms or molecules that produce them, and thus can be used to study the physical properties of those substances. Spectra can be either discrete or continuous. Discrete spectra have individual, sharp peaks. Continuous spectra have very broad features that do not resolve into sharp peaks.³

Spectroscopy has a wide variety of applications. Scientists can use spectroscopy to study the structure of new molecules that can be used in medicine.⁴ Forensic investigators can use spectroscopy to determine the identities of narcotics at crime scenes.⁵ Astronomers can use spectroscopy to study far off stars, planets, and galaxies.⁶ Historians can use spectroscopy to identify art forgeries by examining paint pigments.⁷

Manufacturers can use spectroscopy in quality control for items ranging from food to toothpaste.⁸ Spectroscopy is a powerful tool that has applications in a variety of fields.

In this demonstration, spectroscopy is used to analyze the emission spectra of several different light sources. In an effort to encourage interest in chemistry and the STEM field in general, real world examples were given to engage students. To show the relationship between wavelength and color, laser pointers were used. This is due to the fact that lasers are monochromatic in nature, which means the light emitted is composed of a singular wavelength of light.⁹ To demonstrate continuous spectra, emission from incandescent bulbs, sunlight, and LED lights were observed. To demonstrate discrete spectra, fluorescent bulbs were observed. Figure 2.3 shows examples of discrete and continuous spectra, which were obtained from fluorescent bulbs and incandescent bulbs respectively.

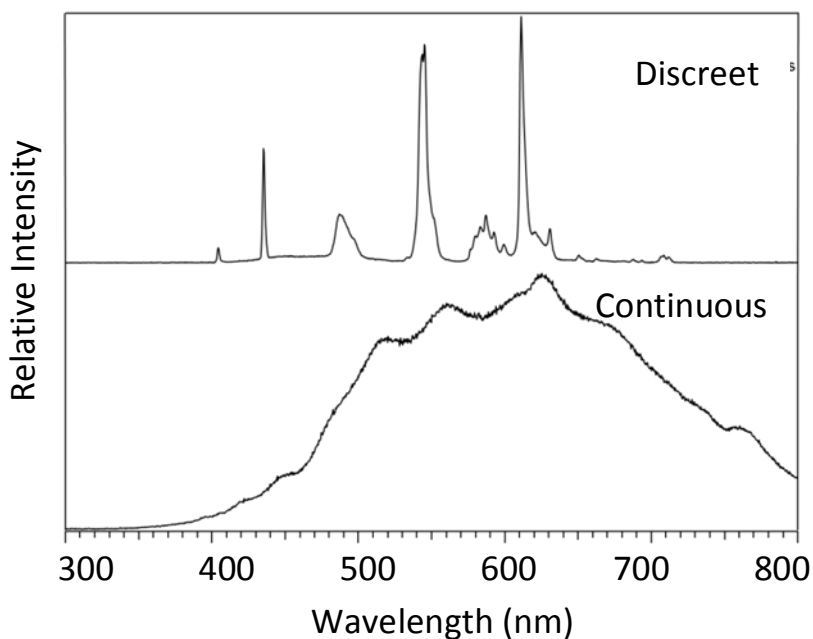


Figure 2.3: *Comparison of discrete and continuous light sources*

2.1.2 Procedure

To determine what material to cover during the demonstration, a list of learning objectives was created. After completing the demonstration, students should be able to explain how color, wavelength, frequency, and energy are related; list the colors of the visible portion of the electromagnetic spectrum in order of increasing energy/decreasing wavelength; calculate the ΔE of an energy transition using Planck's Law; list some everyday uses for lasers; define spectroscopy, absorption, and emission; list some real-world applications of spectroscopy; identify discrete and continuous spectra; and list some examples of discrete and continuous spectra. These learning objectives were used to create the introduction and the assessment sheets.

Before beginning the demonstration, assessment sheets were passed out to the students to determine the extent of their prior knowledge of spectroscopy and the electromagnetic spectrum. A fill-in-the blank worksheet was also passed out for students to complete as the introduction progressed. This was done to help keep students focused and to help prevent them from getting lost.

A simple introduction to spectrometers and how they generate spectra was given to the students before obtaining spectra. To get started, the fiber optic cable was plugged into the Ocean Optics USB2000 portable spectrometer. The spectrometer was plugged into the laptop via a USB port and the Overture program was opened. To begin spectral acquisition, the New Graph icon on the top bar was clicked. Before obtaining spectra, the spectral range was set using the Wavelength Range icon. The range was set from 350nm to 800nm in order to show the full range of the visible portion of the electromagnetic

spectrum. To help show a visual representation of the colors of the wavelengths involved in acquired spectra, the Color icon was selected so that a colored electromagnetic spectrum was overlaid on the emission spectra. Students were asked to volunteer to obtain all spectra in an effort to encourage involvement and increase interest in the demonstration.

To show the relationship between color, wavelength, frequency, and energy, the emission spectra of three different laser pointers were obtained. A violet laser pointer with wavelength of 405nm, a green laser pointer with wavelength of 532nm, and a red laser pointer with wavelength 650nm were used. These wavelengths of laser pointers were used because they correspond to everyday examples students to which students can relate. The violet and red laser pointers were selected because they represent colors at opposite ends of the visible electromagnetic spectrum and because they correspond to the lasers used in Blu-ray players and DVD players. Many of the students possess Blu-ray players and newer generation gaming consoles, which use the 405nm laser, or DVD players and older generation gaming consoles, which use the 650nm laser.¹⁰ The green laser pointer was selected because it corresponds roughly to the mid-point in the electromagnetic spectrum. The relationship between color and wavelength was examined using the spectra of the laser pointers and the energy of the laser pointers was discussed using the Planck equation to correlate energy and wavelength. For more advanced classes, students can calculate the energies of the different laser pointers. The everyday applications of the different lasers and the emission and absorption processes involved in the operation of the lasers were discussed.

To compare different discrete and continuous spectra, a variety of light sources were observed. Spectra of sunlight, an incandescent bulb, and a LED light were used to illustrate continuous spectra. The processes by which these sources cause light emission were discussed and related back to the diagram of absorption vs. emission. The spectrum of a fluorescent bulb was used to illustrate discrete spectra. The process by which fluorescent bulbs operate was discussed. By comparing the spectra of the fluorescent bulb and the incandescent bulb, students were asked to speculate why there has been a shift in the widespread use of incandescent bulbs to fluorescent bulbs. The reasons for this transition were then explained and related to the spectra seen.

To encourage critical thinking and interest in spectroscopy, students were allowed to obtain spectra of various light sources of their choice. They were asked to identify key points of the spectra and discuss the processes by which the light sources emitted light. After the demonstration was complete, assessment sheets were passed out to determine the level of students' understanding of spectroscopy and the electromagnetic spectrum following the demonstration. The pre-assessment and post-assessment sheets were identical. A feedback form was also provided to determine the effectiveness of the demonstration in teaching the concepts presented.

2.1.3 Results and Discussion

The spectroscopy of light demonstration was presented to four classes at the same school. Following the demonstration, students' responses to the pre-assessment, the post-assessment and the feedback form were analyzed. The answers were assigned numerical

scores to facilitate the analysis of the data. Strongly disagree was assigned a value of 1, disagree was assigned a value of 2, neither agree nor disagree was assigned a value of 3, agree was assigned a value of 4, and strongly agree was assigned a value of 5. The average value for each question was obtained. The results of the pre-assessment and the post-assessment were analyzed to investigate the effectiveness of the demonstration in teaching the desired concepts. Some difficulty arose in analyzing the results due to a lack of answers. Some students did not return the assessments or the feedback form while other students did not answer specific questions or provided multiple answers to the same question. The assessments and feedback form can be found in the supplemental documents.

For the pre-demonstration assessment, the average response ranged from 1.64 for question eleven to 3.13 for question six. Question six also showed the highest most common response with a score of four. This question dealt with real-world applications of lasers, so it was expected that this question would receive a higher score. Other than question one, all other questions showed most common answers of either one or two. Questions relating to color and the electromagnetic spectrum showed higher average scores while questions relating to spectroscopy showed lower average scores. The summary of answers for the pre-demonstration assessment can be seen in Table 2.1.

Question	1	2	3	4	5	6	7	8	9	10	11
Number Responses	66	67	66	65	66	64	64	65	65	66	67
Mean	2.64	2.43	1.86	2.03	1.68	3.13	1.72	2.06	1.74	1.65	1.64
Median	3	2	2	2	2	3.5	2	2	2	1.5	1
Mode	3	2	2	1	1	4	2	2	1	1	1
Standard Deviation	0.89	0.99	0.80	1.05	0.68	1.21	0.68	0.90	0.82	0.75	0.77

Table 2.1: *Summary of responses to pre-demonstration assessment questions*

For the post-demonstration assessment, the average response ranged from 3.13 for question four to 3.97 for question two. The most common response ranged from three to four for every question. Questions relating to color and the electromagnetic spectrum and questions relating to spectroscopy showed roughly the same average scores. The summary of answers for the post-demonstration assessment can be seen in Table 2.2.

Question	1	2	3	4	5	6	7	8	9	10	11
Number Responses	38	38	38	38	36	37	37	37	38	38	38
Mean	3.71	3.97	3.66	3.13	3.19	3.95	3.68	3.41	3.58	3.45	3.21
Median	4	4	4	3	3.5	4	4	4	4	3	3
Mode	4	4	3	4	4	4	4	4	4	3	3
Standard Deviation	1.11	0.91	1.12	1.23	1.17	1.08	1.03	1.19	1.08	1.18	1.21

Table 2.2: *Summary of responses to post-demonstration assessment questions*

When comparing the results from the pre-demonstration assessment and the post-demonstration assessment, a shift towards higher scores can be seen. An increase in the

mean and median of the responses were seen across all questions. An increase in the mode of the responses was seen in all questions except for question six, in which the mode remained the same between pre-demonstration and post-demonstration assessments. For all questions except for questions two and six, an increase was seen in the standard deviation. Even though the average response increased, the variation around the mean increased for these questions. A histogram showing the comparison between the average score for each question on the pre-demonstration assessment and the average score for each question on the post-demonstration assessment can be seen in Figure 2.4. As can be seen, the average response increased by one score category, such as from neither agree nor disagree to agree, for most questions. Question six did not show a score category increase. Questions relating to spectroscopy showed the greatest score category increase with questions seven, nine, ten, and eleven increasing by two score categories.

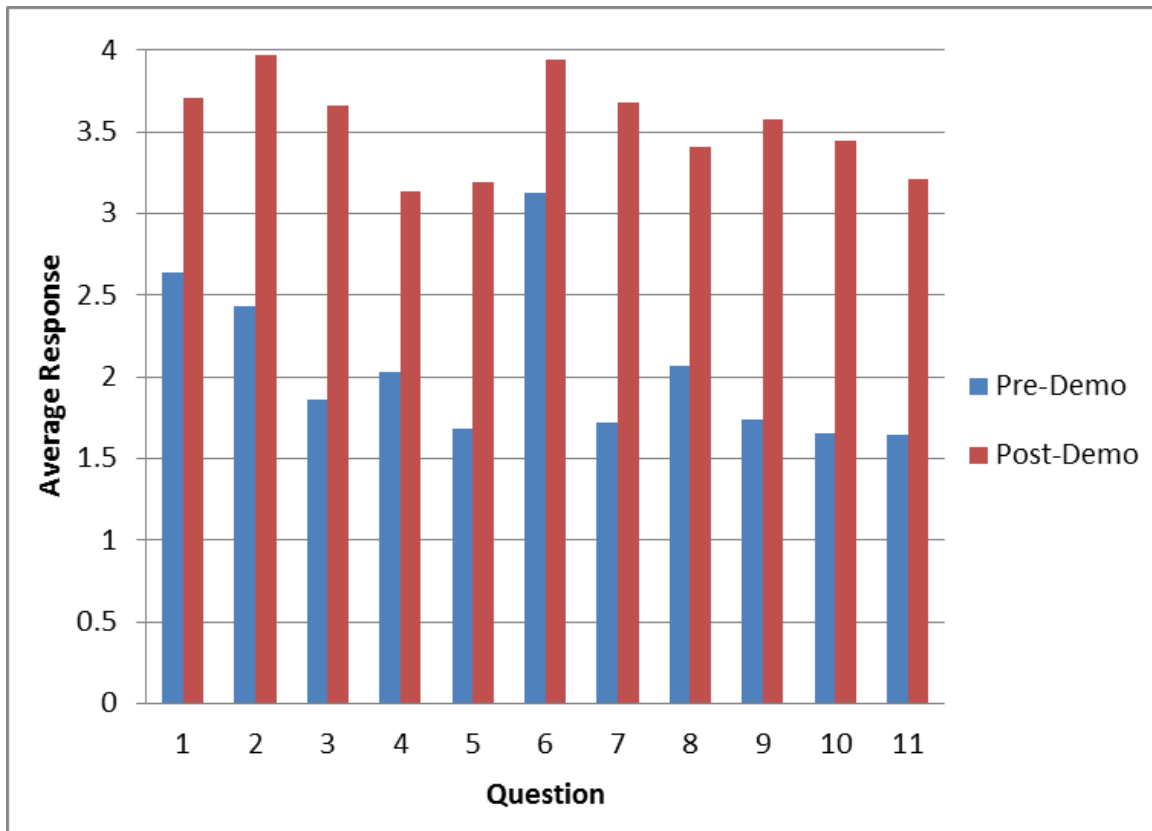


Figure 2.4: Histogram showing the comparison of the average response scores for each question on the pre-demonstration assessment and the post-demonstration assessment

The evaluation of the demonstration showed average responses that ranged from 3.44 for question three to 4.14 for question one. The median score for all questions was four, except for question three that had a median score of 3.5. The mode of the scores for all questions was four, except for question ten that had a mode of five. The evaluation also had an open-ended question where students could leave any additional comments. Only four students wrote responses for this question. All four questions were positive. Three responses dealt with the speaker's performance. The last response dealt with the demonstration itself and was "hands-on experiments = happy students". The summary of answers for the demonstration evaluation can be seen in Table 2.3.

Question	1	2	3	4	5	6	7	8	9	10
Number Responses	37	37	36	36	36	36	36	37	37	37
Mean	4.14	4.03	3.44	3.61	3.89	3.61	3.47	3.68	3.78	3.92
Median	4	4	3.5	4	4	4	4	4	4	4
Mode	4	4	4	4	4	4	4	4	4	5
Standard Deviation	0.79	0.87	0.88	0.84	0.92	1.13	0.97	1.03	0.92	1.04

Table 2.3: *Summary of responses to demonstration evaluation questions*

2.1.4 Conclusions

For all questions in the assessments, an increase in the average response was seen between the pre-demonstration assessment and the post-demonstration assessment. An increase in the median and mode of the responses was also seen for almost all questions. These results suggest that the demonstration was successful in teaching the concepts presented during the introduction. For almost all questions, an increase in the standard deviation was observed between the pre-demonstration assessment and the post-demonstration assessment. In conjunction with the average, this shows that even though there is an increase in the average, the variation around the average is increasing. Ideally, the standard deviation would decrease while the average increased, indicating that more students are marking higher responses to the questions. Some revisions to the demonstration may help achieve this goal. By looking at the post-demonstration responses, it can be seen which topics need to be covered more closely to help students grasp the intended information. By looking at the demonstration evaluation responses,

it can be seen which areas of the demonstration need to be adjusted to help teach the intended information. Ideally, all ten questions would have average response values greater than four. Additional presentations at more schools would help adjust the demonstration to make it more effective in teaching the intended concepts. Visiting additional schools would also help generate more data to better measure the effectiveness of the demonstration. Future school visits have been planned to achieve these goals. Also planned are content knowledge pre-tests and post-tests to ensure that students' actual knowledge of the material before the demonstration and after the demonstration align with the self-reported pre-assessment and post-assessment knowledge levels. This will help control for any self-biases the students may have about their own knowledge.

2.1.5 Supplemental Documents

2.1.5.1 Pre-Assessment/Post-Assessment

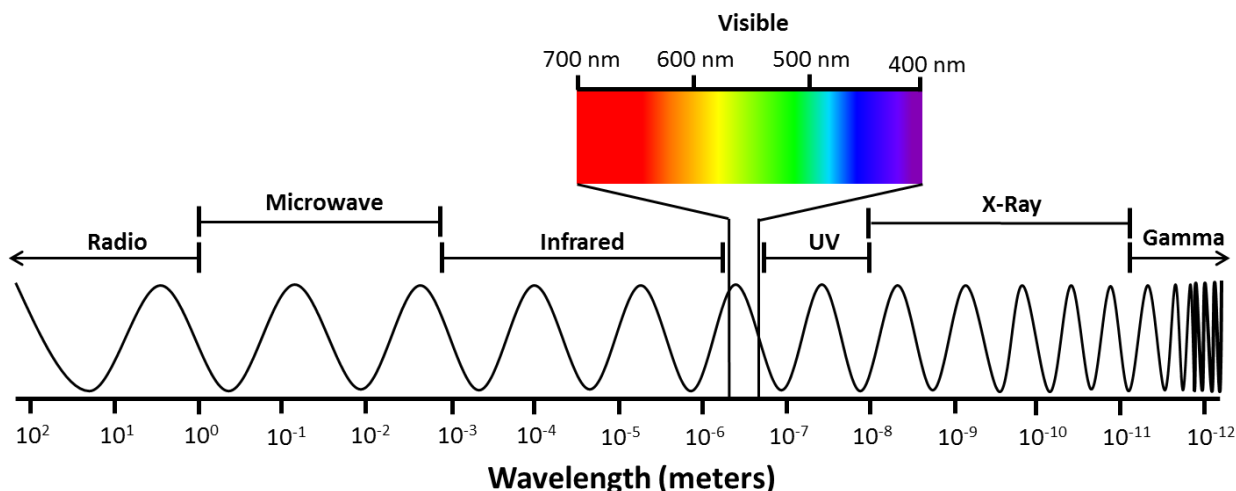
For each question, please select the answer that most closely reflects your understanding of the material.

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
I know how color, wavelength, frequency, and energy are related.					
I know the colors of the visible region of the electromagnetic spectrum.					
I can place the colors of the visible region of the electromagnetic spectrum in order of decreasing wavelength.					
I understand how to calculate the energy of light using the Planck equation.					
I understand the monochromatic nature of lasers.					
I can list some everyday uses for lasers.					
I know what spectroscopy is.					
I can describe absorption and emission.					
I can list some examples of real world applications of spectroscopy.					
I understand the differences in continuous and discrete spectra and can identify the two.					
I can list some examples of continuous and discrete spectra.					

2.1.5.2 Handout

What is light?

When you think of light, you probably think of the colors you can see every day. These, however, represent just a tiny portion of the entire electromagnetic spectrum. Visible light ranges from red at about 700 nm to violet at about 400 nm. In contrast, radio waves, the longest waves in the spectrum, can be several meters long, while gamma rays, the shortest waves in the spectrum, can be shorter than a picometer (10^{-12} m)! In the cartoon below, you can see the electromagnetic spectrum in order of decreasing wavelength.



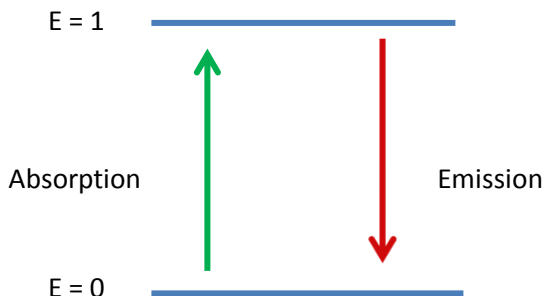
Light is unique in that it exists as both a particle and a wave. The particle form of light exists as tiny packets called photons. Light carries energy. The amount of energy light carries has an inverse relationship to its wavelength and a direct relationship with its frequency. Light of longer wavelengths has lower energies and light of shorter wavelengths has higher energies. The energy of light is a very important factor to consider. Low energy light, such as microwaves, can warm the outside of your skin but not penetrate it. High energy light, such as x-rays, can pass through skin and show the bones underneath! Using the Planck equation (shown below), it is possible to convert the wavelength of light into energy and vice versa. In this equation, E is the energy in Joules, h is Planck's constant (6.626×10^{-34} J·s), c is the speed of light (3.0×10^8 m/s), and λ is the wavelength of the light in meters.

$$E = \frac{hc}{\lambda}$$

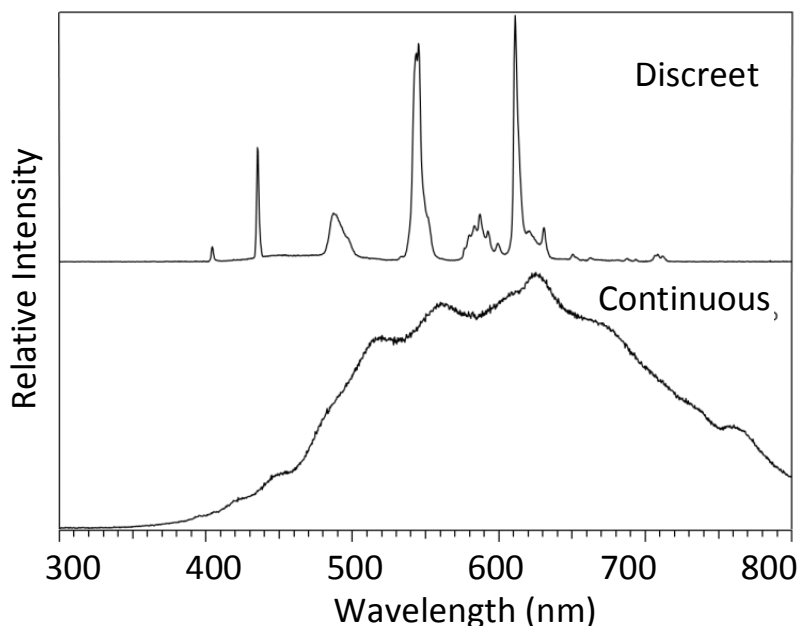
What is spectroscopy?

Spectroscopy is the study of light-matter interactions. When you shine light on matter, there is the possibility that the photons can be absorbed. When this absorption occurs, atoms or molecules can be excited from their ground state to an excited state of higher

energy due to the transfer of energy from the photon to the atom or molecule. This occurs if the energy of the photon matches the energy gap between the ground state and the excited state of the atom or molecule. After the electron is excited, it can release energy in the form of a photon to return to lower energy states. This is known as emission. The processes of absorption and emission can be seen in the diagram below.



Spectroscopy is useful in chemistry because it can be used to study molecules. Each molecule exhibits different patterns of absorption and emission. These patterns are known as spectra. When looking at molecules, you can look at their absorption spectra to see what wavelengths of light they absorb when going to the excited state, or you can look at their emission spectra to see what wavelengths of light they emit when going back down to the ground state. These spectra can be either discrete or continuous. Discrete spectra have individual, sharp peaks that occur from specific energy levels. Continuous spectra have very broad peaks that result from many different energy levels all at the same time. In the picture below, you can see examples of both continuous (an incandescent light bulb) and discrete (fluorescent light bulb) spectra. Spectroscopy can be used to determine the structure and other physical properties of atoms and molecules.



Spectroscopy has many real-world applications. Scientists can use spectroscopy to study the structure of newly synthesized molecules that can be used in medicine. Forensic

investigators can use spectroscopy to determine the identity of unknown drugs at crime scenes. Astronomers can use spectroscopy to study very distant stars, planets, and galaxies. Historians can use spectroscopy to identify forgeries in art by examining paint pigments. Manufacturers can use spectroscopy in quality control for items ranging from food to toothpaste. Spectroscopy is a very powerful tool that is used in many different fields.

2.1.5.3 Worksheet

What is light?

1. The broad range of all the wavelengths of light is known as the _____.
2. The colors of the visible spectrum range from _____, which has the lowest energy and the longest wavelength, to _____, which has the higher energy and the shortest wavelength.
3. Light exists as both _____ and _____.
4. Particles of light are called _____.
5. Laser light is _____, which is why we used it to demonstrate the relationship between color, energy, and wavelength.

What is spectroscopy?

6. Spectroscopy is the study of _____ - _____ interactions.
7. When _____ occurs, substances are excited to high energy states; when _____ occurs, substances relax from high energy states to ground states.
8. The patterns of absorption or emission of light of substances are known as _____.
9. Spectroscopy can be used to study the _____ of substances.
10. Spectra can be either _____ and have sharp peaks or _____ and have broad features.

2.1.5.4 Feedback Form

For each question, please select the answer that agrees most closely with your experience with the demonstration.

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
This demonstration helped me understand the relationship between color, wavelength, frequency, and energy.					
This demonstration helped me learn order of colors in the visible region of the electromagnetic spectrum.					
This demonstration helped me learn how to calculate the energy of light using the Planck equation.					
This demonstration helped me understand the monochromatic nature of lasers.					
This demonstration helped teach me about spectroscopy.					
This demonstration helped me understand the difference between continuous and discrete spectra.					
This demonstration helped me learn how to analyze spectra.					
This demonstration was easy to understand.					
This demonstration was useful in teaching the concepts presented in the introduction.					
I enjoyed this demonstration.					

2.2 References

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- (3) Engel, Thomas, and Philip Reid, *Physical Chemistry*, 3rd ed, **2013**, 310.
- (4) W. He, Y. Li, C. Xue, Z. Hu, X. Chen, F. Sheng, "Effect of Chinese Medicine Alpinetin on the Structure of Human Serum Albumin", *Bioorganic & Medicinal Chemistry*, **2005**, 13(5), 1837-1845.
- (5) A. Ryder, "Classification of Narcotics in Solid Mixtures Using Principal Component Analysis and Raman Spectroscopy", *Journal of Forensic Sciences*, **2002**, 47(2), 275-284.
- (6) "Infrared Spectroscopy in Astronomy", California Institute of Technology
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- (8) Da-Wen Sun, *Infrared Spectroscopy for Food Quality Analysis and Control*, **2009**, 179-414.
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- (10) "Blu-ray FAQ", Blu-ray.com, <<http://www.blu-ray.com/faq/>>.

3 Attracting College Undergraduates to STEM Degrees

3.1 Creation of a Website to Involve Students in the Ole Miss Physical Chemistry Summer Research Experience for Undergraduates Program

Studies have shown that involvement in programs that foster peer-to-peer and student-to-faculty relationships help increase retention rates in programs.¹ In order to increase involvement in and knowledge of the Ole Miss Physical Chemistry (PChem) Summer Research Program and the Ole Miss Research Experience for Undergraduates (REU) Program, a visually appealing and easy-to-navigate website was designed. A prior website had existed for the Ole Miss PChem Summer Research Program, but it was remade to be more user friendly. The REU website was designed to integrate smoothly with the new Ole Miss PChem Summer Research Program website. Both websites were designed using iWeb version 3.0.2.

Creation of the Ole Miss PChem Summer Research Program website began with the home page. More links were added to the navigation bar to make the website easier to navigate. The group picture of the previous year was added to the home page to help show the level of involvement in the program and to make the page more visually appealing. Figure 3.1 shows the old version of the website home page. Figure 3.2 shows the new version of the website home page.

Home

Schedule

Faculty & Staff

Students

2009

Center for Experimental & Theoretical
Physical Chemistry @ Ole Miss

- Summer Research Institute -

The goals of the annual Ole Miss PCHEM Summer Research Institute are to:

- (1) Foster communication and collaboration between the members of the different physical chemistry groups,
- (2) Have training in the form of lectures and mini-courses from the faculty,
- (3) Offer the opportunity for students to learn how theory and experiment work together, and
- (4) Offer the opportunity for students (both undergrad and grad) to present research talks (20 or 40 min) to a large (20+) peer audience.

The Ole Miss PCHEM Summer Research Institute is supported by The National Science Foundation (300223109A).

Figure 3.1 Home page for the old Ole Miss PChem Summer Research Program website



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— Summer Research Program —

[PCHEM Home](#) | [Senior Faculty](#) | [Research Projects](#) | [Program Participants](#) | [PCHEM Schedule](#)
[Group Pictures](#) | [Social Activities](#) | [REU Home](#) | [REU Student Profiles](#)

The goals of the annual Ole Miss PCHEM Summer Research Program are to:

- (1) Foster communication and collaboration between the members of the different physical chemistry groups,
- (2) Provide training in the form of lectures and mini-courses from the faculty,
- (3) Offer the opportunity for students to learn how theory and experiment work together, and
- (4) Allow students (both undergraduate and graduate) to present research talks (20 to 40 min) to a large (20+) peer audience.



Ole Miss PCHEM 2014

The Ole Miss PCHEM Summer Research Program is supported by The National Science Foundation (EPS-0903787, CHE-0957317, CHE-0955550, and CHE-1156713).



Figure 3.2 Home Page for the new Ole Miss PChem Summer Research Program website

The next page to be designed was the senior faculty page. Whereas the old senior faculty page on the Ole Miss PChem Summer Research Program website only had the professors' names listed and hyperlinked to their Ole Miss Chemistry Department profile pages, the new webpage includes their pictures and names hyperlinked to their groups' websites. Like on the first page, the pictures of the faculty were added to make the website more visually appealing. A link was also added to the bottom of the webpage to allow students to learn more about the other faculty members they might interact with in the department during the course of the summer program. The old Ole Miss PChem Summer Research Program faculty page can be seen in Figure 3.3. The new Ole Miss PChem Summer Research Program faculty page can be seen in Figure 3.4.

The program participants page also underwent significant revisions. The old Ole Miss PChem Summer Research Program had all of the students listed in multiple columns in alphabetical order. On the new Ole Miss PChem Summer Research Program page, participants' names were broken up into groups based on the research group they were working in. This was done in an effort to illustrate the number of research groups involved in the summer research program and to divide up the names in a manner that made them easier to process. REU students were designated with asterisks. The old webpage format can be seen in Figure 3.5. The new webpage format can be seen in Figure 3.6.

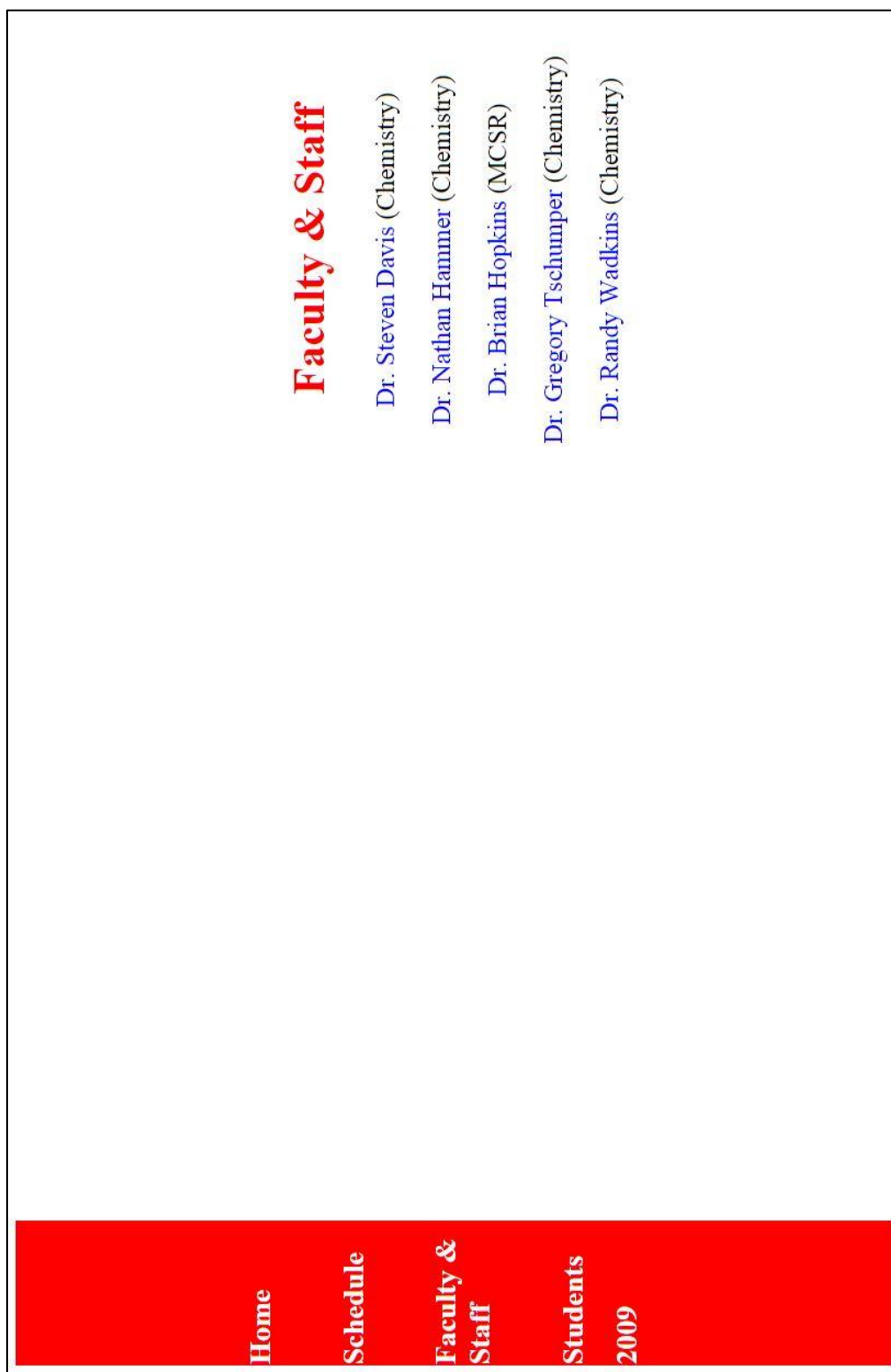


Figure 3.3 Faculty Page for the old Ole Miss PChem Summer Research Program website


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 – Summer Research Program –

[PCHEM Home](#) [Senior Faculty](#) [Research Projects](#) [Program Participants](#) [PCHEM Schedule](#)
[Group Pictures](#) [Social Activities](#) [REU Home](#) [REU Student Profiles](#)

Senior Faculty


 Dr. Nathan Hammer
 (Chemistry)
 Program Director


 Dr. Gregory Tschumper
 (Chemistry)
 Program Co-Director


 Dr. Steven Davis
 (Chemistry)


 Dr. Jared Delcamp
 (Chemistry)

Figure 3.4 Faculty Page for the new Ole Miss PChem Summer Research Program website

Home
Schedule
Faculty & Staff
Students
2009

Students

Desiree Bates	Bei Cao
Emily Carrell	Kari Copeland
Eric Dornshuld	Coleman Howard
Lynn Joe	Annie McClellan
Matt McDowell	Katie Munroe
Peter Nix	Samantha Reilly
Nikki Reinemann	Debra Jo Scardino
Evan Stock	Shanna Stoddard
Ginger Tipton	Jeffrey Veals
Ashley Wright	Shawn Yu
Zhendong Zhao	

Figure 3.5 Participants page for the old Ole Miss PChem Summer Research Program website

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– Summer Research Program –

[PCHEM Home](#) [Senior Faculty](#) [Research Projects](#) [Program Participants](#) [PCHEM Schedule](#)
[Group Pictures](#) [Social Activities](#) [REU Home](#) [REU Student Profiles](#)

2014 PChem Participants

Hammer Group:

- John Kelly
- Louis McNamara
- Kristina Cuellar
- April Steen
- Peyton Reves
- Ashton Nicholson
- Sarah Sutton
- Danielle George
- Jordan Cauley *
- Lawson Lloyd *

Tschumper Group:

- Thomas Ellington
- Katelyn Dreux
- Eric Van Dornshuld
- Coleman Howard
- Alexandra Baumann
- Nick Feaster
- Blake Sowers
- Sarah N Johnson
- Jakob Anderson *
- Spencer Hinton *

Doerksen Group:

- Manal Nael
- Kuldeep Roy
- Pankaj Pandey
- Shuneize Slater
- Veena Gadepalli
- Trent Todd
- Austin Ezell
- Ashlee Colbert *
- Michael Concepción *

Figure 3.6 *Participants Page for the new Ole Miss PChem Summer Research Program website*

The final page to undergo revisions from the original website was the program schedule page. On the old schedule page, meetings, lectures by professors, and workshops were listed with specific details. Student seminars were only listed with that designation, the place, and the time. On the new schedule page, details were also added to the student presentations. Each student presentation listed the name of the presenter and the title of their presentation. Student seminars were designated with blue lettering and lectures by professors were designated with red lettering. Social activities were also added to the new calendar. The old layout for the calendar can be seen in Figure 3.7. The new layout for the calendar can be seen in Figure 3.8.

In addition to revising the old website pages to make them easier to navigate and more visually appealing, new pages were added. A research projects page was added to make it easier for students to learn about the projects involved in the Ole Miss PChem Summer Research Program and the REU program. The research projects were divided up by research group to help students find a research group they would want to work in. A group pictures page was added to show the growth of the program over time. The group pictures page highlights the rapid growth the program has experienced since its creation in 2009. A social activities page was added to show the interaction between students and faculty and the team building that occurred during said activities. The professional relationships and contacts formed during the program are hugely beneficial to participants and are a major point of the program.

Home Schedule Faculty & Staff Students 2009	Monday	Tuesday	Wednesday	Thursday	Friday
	June	1	2	3	4
	7 Organizational Meeting Coulter Hall 200 2:00pm Lectures by Profs. Hammer and Tschumper	8	9 Scripting Classes Weir Hall 104 2:00-5:00pm	10	11 Lectures by Profs. Davis and Wadkins Coulter Hall 200 2:00pm Scripting Classes Weir Hall 104 3:00-5:00pm
	14 "Vibrational Spectroscopy" Prof. Hammer	15 C/C++ Workshop Weir Hall 104 3:00-5:00pm	16	17 C/C++ Workshop Weir Hall 104 2:00-5:00pm	18 C/C++ Workshop Weir Hall 104 2:00-5:00pm
	21 "Quantum Chemistry" Prof. Tschumper	22	23	24	25
	28 Student Seminar Coulter Hall 200 2:00pm	29	30	July 1	2 Student Seminar Coulter Hall 200 2:00pm
	5 Student Seminar Coulter Hall 200 2:00pm	6	7	8	9 Student Seminar Coulter Hall 200 2:00pm
	12 Student Seminar Coulter Hall 200 2:00pm	13	14	15	16 Student Seminar Coulter Hall 200 2:00pm
	19 Student Seminar Coulter Hall 200 2:00pm	20	21	22	23 Student Seminar Coulter Hall 200 2:00pm

Figure 3.7 Calendar page for the Ole Miss PChem Summer Research Program website

				
PCHEM Home Senior Faculty Research Projects Program Participants PCHEM Schedule Group Pictures Social Activities REU Home REU Student Profiles				
2014 Schedule				
Red = Lecture by Professor Blue = Lecture by Student				
Monday	Tuesday	Wednesday	Thursday	Friday
May 26	27	28	29	30
		REU Students Arrive Check into Residence Hall, Pick up ID, Get Parking Pass	Meet in Coulter Hall Room 200 at 9:00am Introductions and Online Research Training Introductory Computational Chemistry Classes: "Linux" Weir Hall 2:00pm-5:00pm	Health & Safety Training - either at 8:00am or Noon Continue Online Research Training Introductory Computational Chemistry Classes: "Scripting" Weir Hall 2:00pm-5:00pm
June 2	3	4	5	6
Meet with Research Groups at 9:00am Lecture by Eric Van Dornshuld Coulter Hall 200 1:00pm "Literature Searching Using the UM online Library" Introductory Computational Chemistry Classes: "Z-Matrices & Gaussian" Weir Hall 2:00pm-5:00pm	Group Picture and Lecture by Prof. Gregory Tschumper Coulter Hall 200 2:00pm "Intro to Computational Quantum Chemistry I: Overview and Convergent QC (Methods and Basis Sets)"	Lecture by Prof. Gregory Tschumper Coulter Hall 200 2:00pm "Intro to Computational Quantum Chemistry II: Convergent QC and Scaling Illustrated with Water Clusters"	Social Activity Basketball Turner Center Noon-1:00pm Lecture by Prof. Gregory Tschumper Coulter Hall 200 2:00pm "Intro to Computational Quantum Chemistry III: Scaling vs. Massively Parallel Supercomputing"	Introductory Computational Chemistry Classes: "MCSR systems" Weir Hall 2:00pm-5:00pm

Figure 3.8 Calendar page for the new Ole Miss PChem Summer Research Program website

A REU website was created and integrated into the regular Ole Miss PChem Summer Research Program website. On the REU home page, the program flyer and a description of the program were added. Hyperlinks were included for the program application and the REU specific program calendar. The REU home page can be seen in Figure 3.9. A REU student profile page was also created to show past program participants, the independent research projects they undertook while enrolled in the program, their home colleges, their faculty advisors, and their pictures. Hyperlinks were also included at the bottom of the page that linked to past REU participant profiles. The REU program participants page can be seen in Figure 3.10.

The updates to the Ole Miss PChem Summer Research Program website and the creation of the REU program website were done to increase the effectiveness with which knowledge of the program was disseminated. Increasing the visual appeal, simplifying the navigation around the website, and adding additional information were done in an effort to increase students' interest in participating in the program. The goals of the Ole Miss PChem Summer Research program and the REU program include increasing student participation in the sciences and retaining students in the STEM field after they graduate from their undergraduate studies.² The Ole Miss Physical Chemistry Summer Research Program website can be viewed at phys.chem.olemiss.edu. The REU program website can be viewed at reu.chem.olemiss.edu.

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— Summer Research Program —

PCHEM Home Senior Faculty Research Projects Program Participants PCHEM Schedule
Group Pictures Social Activities REU Home REU Student Profiles

NSF REU @ Ole Miss

[Click Here for 2015 Application](#) (Save and Open in Adobe Acrobat Reader)

The Ole Miss Physical chemistry Research Program seeks applicants for a summer Research Experience for Undergraduates (REU) program. Ten non-University of Mississippi students who have completed their freshman year of college and who have not yet graduated can participate fully in the Ole Miss Physical Chemistry Research Program activities and work on a research project under the direction of a faculty advisor. Student participants will receive a \$5,000 stipend, a housing and meal plan for ten weeks, and travel assistance. Undergraduate student participants must be citizens or permanent residents of the United States or its possessions. For more information, contact program director Dr. Nathan I. Hammer at nhammer@olemiss.edu.

[Click the links to view REU Flyer or REU Calendar.](#)

Figure 3.9 Home page for the Ole Miss REU program website



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– Summer Research Program –

[PCHEM Home](#) | [Senior Faculty](#) | [Research Projects](#) | [Program Participants](#) | [PCHEM Schedule](#)
[Group Pictures](#) | [Social Activities](#) | [REU Home](#) | [REU Student Profiles](#)

2014 REU Participants

	<p style="text-align: center;">Jakob Anderson</p> <p>Home College: Belhaven University Faculty Advisor: Gregory Tschumper Project Title: Computational Study of Novel Heterocyclic Structures for Dye Sensitized Solar Cells</p>
	<p style="text-align: center;">Jordan Cauley</p> <p>Home College: Mississippi College Faculty Advisor: Nathan Hammer Project Title: Spectroscopic and Computational Studies of Urea/TMAO/Water Solutions</p>
	<p style="text-align: center;">Ashlee Colbert</p> <p>Home College: Florida A&M University Faculty Advisor: Robert Doerksen Project Title: An Analysis of Water and Pyrimidine-Containing ATP Competitive Inhibitors on GSK-3B: A Computational Study</p>
	<p style="text-align: center;">Michael Concepción</p> <p>Home College: Universidad Metropolitana, Recinto de Cupey Faculty Advisor: Robert Doerksen Project Title: Computational Analysis of Aminopyrimidine Inhibitors of Protein Kinase GSK-3B</p>
	<p style="text-align: center;">Arielle Hackel</p> <p>Home College: Georgia State University Faculty Advisor: Randy Wadkins Project Title: Molecular Modeling of siRNA-Binding Cationic Copolymers</p>

Figure 3.10 *Participants page for the Ole Miss REU program website*

3.2 Program Statistics

Since its implementation in 2009, the Ole Miss Physical Chemistry Summer Research Program has hosted many University of Mississippi undergraduate and graduate research assistants. Nineteen papers that include undergraduate authorship have resulted. Fourteen participants have gone to graduate school in a STEM field and seventeen participants have gone into a post-undergraduate medical program. Two Goldwater scholars and five postdoctoral candidates have also emerged from among the participants. The Ole Miss PChem Summer Research Program has a history of recruiting students that obtain degrees in the STEM field.² It is hoped the implementation of the new Ole Miss PChem Summer Research Program website will allow more students to learn about the program and will attract more participants in the future.

Since its implementation in the summer of 2012, the Ole Miss REU program has had twenty participants. The first year of the program, there were 35 applicants. The second year, after the creation of the new websites, the number of applicants increased to 51. The number of applicants for this coming summer has increased slightly to 53. Of the first cohort, six have graduated with undergraduate science degrees. Two REU students have gone to graduate school in a STEM field, two have gone into a post-undergraduate medical program, and two have entered the chemical industry. Two REU students have served as co-authors on papers in major chemical research journals. The program has also made a point of including minority groups to encourage their retention in the STEM field. Of the twenty participants in the program, 20% have been African American and 50% have been female. Response to the program has been encouraging, with students giving an average score of 4.1 out of 5 indicating they wish to pursue a

graduate program in the sciences. Several students have commented that the program has helped them discover what they want to do after graduation and encouraged them to pursue a career in the STEM field.² It is hoped that this REU program will continue to inspire students to pursue STEM degrees and that the websites created will help disseminate information on these programs to encourage students' interest and participation.

3.3 References

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